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The Story of Gliding (Murray)

FRANK IRVING

An Introduction to the Longitudinal Static Stability of Low Speed Aircraft (Pergamon)

NEW SOARING PILOT

Ann and Lorne Welch
and Frank Irving

THIRD EDITION
REVISED AND ENLARGED

JOHN MURRAY

satisfaction that a successful flight can bring.

One feature of soaring since its inception has been competitions at both National and International levels. There is no doubt that these contests have done much to improve our knowledge of soaring, and this has occurred in two ways. Firstly by pilots attempting to put up good performances in conditions which they consider unsuitable or difficult, and secondly by observing how their competitors fly, and by talking with them. Pilots visiting other countries have found that although the conditions in terms of thermal strengths, heights of cloud base and so on, may be different to those which they are accustomed, the actual technique varies but slightly, and in general local knowledge is of less importance than might be supposed. A clear mind free of preconceived ideas is often more successful.

One good feature of soaring is the friendship between gliding people of different countries. The small badges worn by soaring pilots are similar all over the world, and the wearer can be sure of a welcome wherever he goes. The reason for this is that the sort of people who go in for gliding are similar in all countries. They do it because they like it, there being little or no commercial incentive, and they share a desire to find out more about the air in which they fly, with its varieties of solitude and violence, beauty and challenge.

Chapter 3

Circling in Thermals

Most soaring is carried out using warm air upcurrents called thermals. They are created by the sun and so occur only during the day. This automatically puts a limit to the length of a thermal soaring flight. The whole art of soaring has, as a result, been devoted to developing techniques to enable the maximum to be extracted from the weather in the time available.

Thermals occur as a result of the irregular heating of the earth's surface, and take the form of bubbles or patches of warmed, buoyant air which rise until they have cooled to the temperature of the surrounding air, or have reached a layer of air as warm as or warmer than themselves. As the thermal rises and cools it will become less able to hold its moisture in the invisible vapour state, and will produce cumulus cloud if condensation level is below the level at which the thermal reaches its equilibrium.

The pilot uses thermals by circling to keep in the rising air. When he has gained enough height he flies off in search of more lift. By choosing his route he can fly across country or soar locally around the airfield (Fig. 3.1). Although a vast amount of thermal soaring has been done, there is little quantitative information available about the distribution, size or strength of thermals, or about the structure of the individual thermal. (See Appendix 8.) However, it is well known that the characteristics of thermals can vary from a diameter of a few feet to an area of several square miles. The smallest thermal which can effectively be used by a glider is about 400 ft across, but in general the thermals used are larger than this and 1000 ft may be taken as a typical diameter. Thermals may also be smooth or rough, and circular or otherwise in cross section.

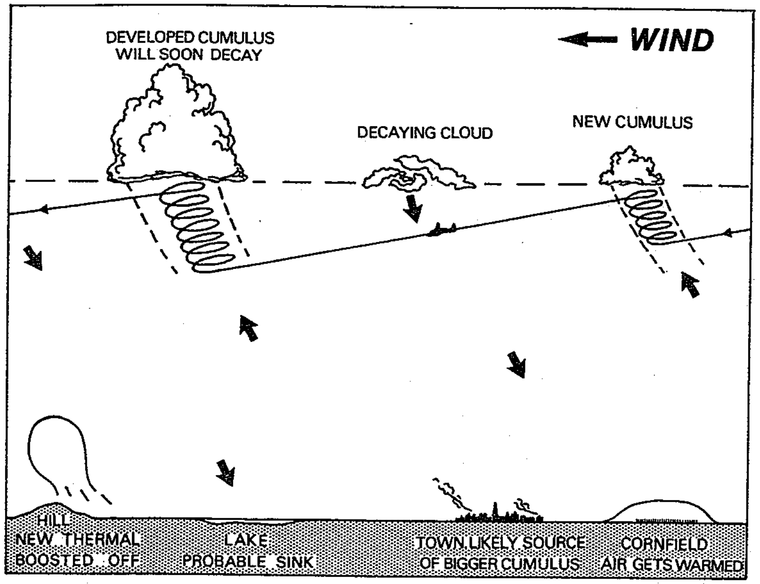

Fig 3.1 Simplified progress of glider flying across country

All these variations demand different techniques, and so to avoid complication this Chapter will deal with what might be called average conditions; a horizontal cross section through a thermal will be taken as circular, with the lift strongest in the middle and decreasing towards the outside.

Let us imagine that the pilot has had an aerotow on a typical European summer day with small cumulus at 4000 ft, and is now gliding straight at about 2000 ft. He is not in lift but the air will not feel entirely steady, and the variometer will show about 2 knots sink. Sooner or later he may fly into a thermal. Just before he does so the air will probably feel rougher and the rate of sink increase. The entry into a good thermal may be marked by a sort of 'woosh' as the airspeed increases and the glider surges upward. After a lag of a second or two the variometer will show climb. The air inside the thermal often has an effervescent feel unlike that

outside. As the glider flies through the thermal the rate of climb increases and when the centre is passed starts to decline. Quite suddenly the glider flies out of the lift, and there may be a sort of 'woomp' as the airspeed decreases and the glider sinks. Then after the usual slight lag the variometer will show sink once more. The time taken to fly through the thermal will, of course, depend on its size and on the speed of the glider. For the thermal shown in these diagrams – 1100 ft diameter – the time taken to fly through it at 40 knots will be 16 seconds. If the mean rate of climb in it were 3 knots the glider would gain about 80 ft.

If the straight path is continued another thermal may not be met for a mile or more, by which time the glider will have lost more height than it gained in flying through the thermal.

Introduction to Figs. 3.2-9. The following figures show a highly idealized state of affairs in that the themal is of exactly circular cross section, and has a sharply defined edge. In practice the thermal will probably be of less regular shape and its edge will not be clearly marked. For simplicity the problem has been considered as that of getting into the thermal, but the problem of shifting the circles into the best lift can be tackled in exactly the same way. In each case the figures are on the same scale with a thermal of 1100 ft diameter. The glider is assumed to be an intermediate type with a span of 50 ft and to be flying at a constant speed of 40 knots. When it circles it does so at an angle of bank of 30°. A turn made at this speed and angle of bank will have a radius of 250 ft; the time taken to complete a 360° turn will be 23 seconds. It is assumed that the glider takes 3 seconds to attain 30° of bank from straight flight and the same time to straighten up from the turn. The commencement of the turn from straight flight and the resumption of straight flight from the turn are shown by small squares. The point at which the glider is fully in the turn and the point at which it starts to come out of the turn are shown by small circles. In the diagrams and explanations it is assumed that the glider is fitted with a non-electric variometer having a lag of a few seconds.

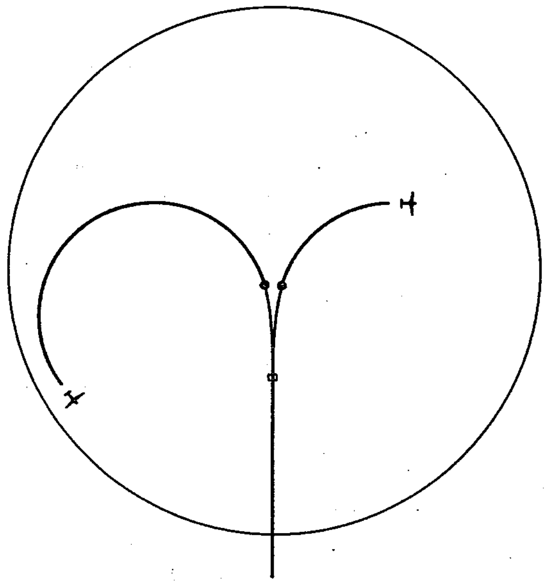

Fig 3.2 Which way to turn? (i) If the thermal is entered with the glider heading towards the centre, it does not matter which way the turn is made

It is, therefore, usually necessary to gain height by circling for some time and then converting this height into distance by gliding straight until another thermal is encountered. The process is then repeated.

Direction of turn. On hitting a thermal the pilot must decide in which direction to start circling. If the glider enters the lift heading towards the centre it obviously does not matter in which direction the turn is made (Fig. 3.2). But if the flight path passes along the edge of the thermal, a circle in one direction will be almost completely outside it, while a circle the other way will be in it (Fig. 3.3). Fortunately it is often possible to tell on which side the stronger lift is to be found, as on entering a thermal the wing nearer the centre may be lifted up first. If this occurs the

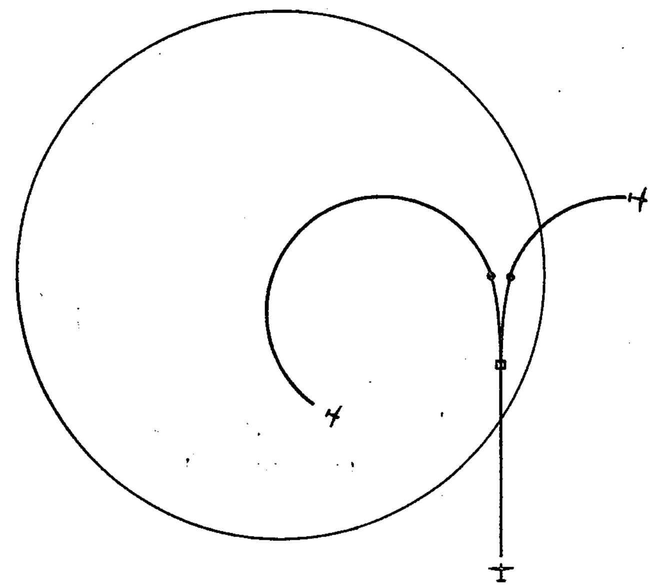

Fig 3.3 Which way to turn? (ii) If the glider flies into the side of a thermal, to turn in one direction will be good; to turn the other way will result in most of the circle coming outside the thermal. Often the fact that the glider has entered the side of the thermal can be discovered as one wing will be pushed up first. In the diagram above the glider will tend to bank to the right on entering the thermal. The pilot should prevent the left wing from lifting and then push it down and turn left

pilot should put it down again, fly straight for a second or so, and then start to turn towards the wing which was lifted up.

If any other gliders are already using the lift there is a convention which requires new arrivals to circle in the same direction as those already there in order to minimise the risk of collision.

Methods of Centring. If the pilot starts to circle as soon as he enters the lift, half the circle will be inside and half out-

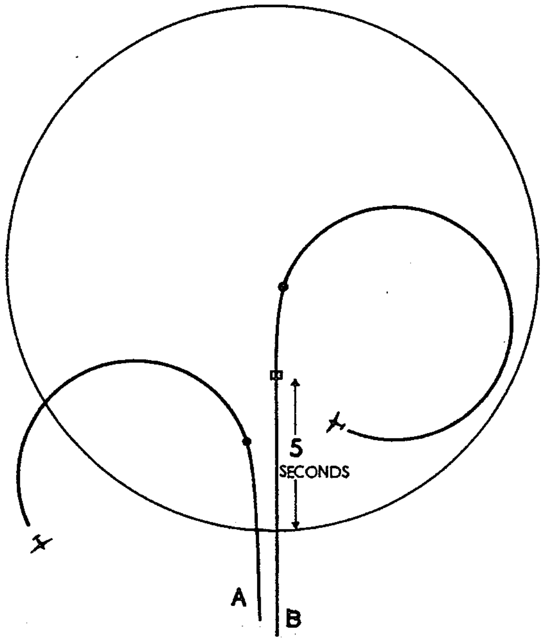

Fig 3.4 How soon to start turning? (i) If the entry is made flying towards the centre of the thermal, and the turn is started immediately, most of the circle will be outside the thermal (path A*). Instead, the pilot should fly straight for at least five seconds before starting his turn (path* B*). Of course, if there is reason to believe that the thermal is large, straight flight should be maintained for a longer time*

side the thermal (Fig. 3.4). On the other hand if he waits until he has got to the middle by seeing when the variometer reading starts to decrease, he will probably fly out of the far side as he does his turn. There are a number of different ways of centring; by tightening and loosening the circles, by side-slipping, by reversing the direction of the turn, or by straightening up and then turning again. Each method has its adherents, and they all seem to work, but the simplest is that of

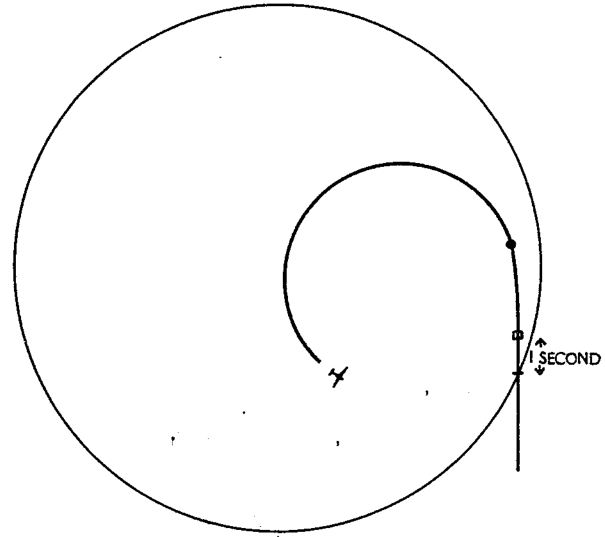

Fig 3.5 How soon to start turning? (ii) If it is suspected that the glider has flown into the side of the thermal, by one wing being pushed up, the turn should be made almost immediately after a pause of only a second or so

straightening up for a short while in the appropriate direction.

The Worst Heading Method. The pilot should notice, by reference to the sun, a cloud, or something prominent on the ground, the direction in which the glider is heading when the variometer shows most sink. Let us say that during a circle the variometer indicates the greatest sink when the glider is facing the sun. This should be checked by doing another circle to see if the same result is obtained. The pilot should then continue turning, but straighten up 60° after passing the sun, fly straight momentarily, and then start circling in the same direction as before. This will have shifted the circle about 200 ft to one side. The reason for turning 60° and not 90°, as might be supposed, is to make allowance for the lag of the ordinary variometer; due to this lag the

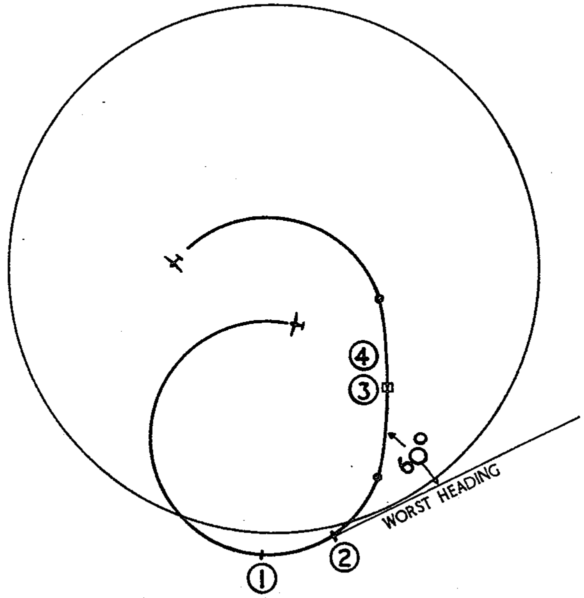

Fig 3.6 Worst Heading method of centring
1 Glider is worst off here
2 Owing to the lag in the variometer it shows that the glider is worst off here. Pilot should observe the aircraft's heading
3 Pilot straightens up 60° later
4 As soon as he is straight he should start to turn again in the same direction
This manoeuvre will have shifted the circle by about 200 ft

instrument will show greatest sink about 2 seconds after the point at which it was actually experienced. If an electric variometer is used the turn should be made through nearly 90°, since the instrument has virtually no lag.

This method may sound mechanical; it is meant to be, because however confused the pilot may become it can be applied easily. All that he has got to do is to decide in which direction he is heading when worst off, turn a further 60°,

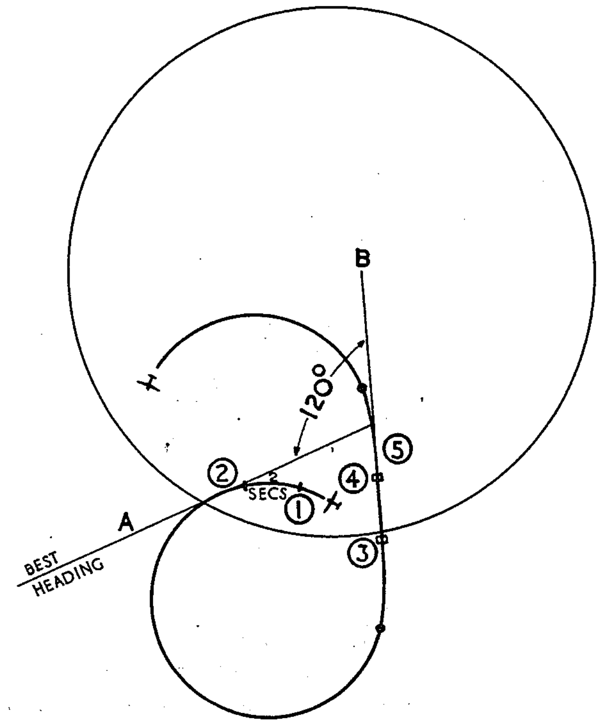

Fig 3.7 Best Heading method of centring.
1 Glider has maximum rate of climb here
2 Owing to the lag of the variometer it shows best rate of climb here. The pilot should observe either (A) the heading or (B) what is under the higher wing tip
3 Pilot continues circling and straightens up 120° short of heading (A) or, what is the same thing, towards (B)
4 Pilot flies straight for two seconds, or if most of the circle has been bad, for a longer time
5 Pilot starts circling again in the same direction as originally

straighten up the glider and forthwith start turning the same way as before (Fig. 3.6).

The Best Heading Method. If most of the circle is in sinking

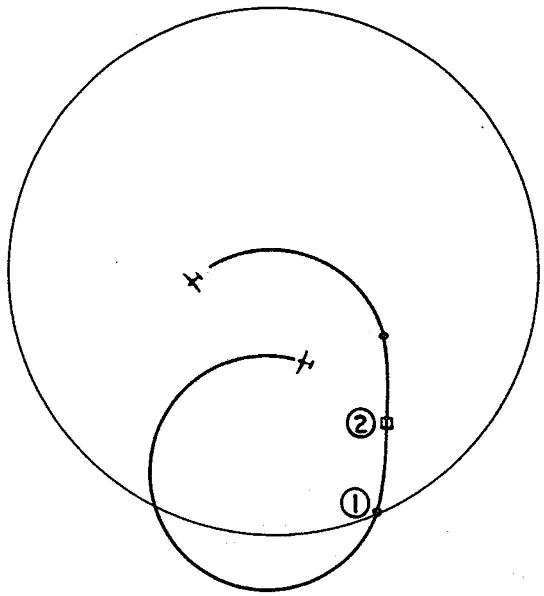

Fig 3.8 Surge method of centring
1 On entering thermal, the glider surges upwards. The pilot should immediately start to straighten up
2 As soon as the aircraft is straight, the turn should be started in the same direction as before

air outside the thermal it is difficult to decide in which direction the glider is heading when it is worst off, because the variometer may show steady sink for a prolonged period. In this case it is easier to decide in which direction the glider is going when it is doing best. The turn should be continued for a little less than 240° from this heading, and then straightened up for one or two seconds before starting to turn again (Fig. 3.7).

It is useless altering the position of the circles unless the pilot is quite certain in which direction they should be shifted, and so to begin with it will be better to do at least two steady circles noticing the distribution of the lift before

taking any action. Most people, when learning, alter their circles too frequently, and often lose the thermal in the process.

The Surge Method. Another way of getting into the best lift is to straighten up for a second or two whenever a real surge of lift is felt, or observed on the variometer. This method is often easier to apply than those described above, particularly when the area of lift is sharply defined or the air very turbulent, but it cannot be used with large smooth thermals (Fig. 3.8).

Reversing Direction of Turn. Until some experience in thermal soaring has been gained it is inadvisable to reverse the direction of the turn. If an expert pilot finds himself near the edge of the thermal he may change over and turn the other way at the critical moment (Fig. 3.9), but if a beginner tries this he is very likely to lose the thermal completely. As mentioned earlier there are other ways of adjusting the circles besides those shown in the diagrams and the pilot, as he gains experience will adopt the technique which suits him best.

Circling. Once in the thermal the glider should be kept turning smoothly and steadily at a constant angle of bank for at least two complete circles in order to see what happens. With any luck the variometer will now show climb all the way round, and the glider will go up. A thermal is seldom perfectly smooth inside and so the variometer must not be expected to give an entirely steady reading; in fact even little bits of sink may be indicated. If the glider is climbing, the pilot should not worry about this but instead concentrate on making even circles at a steady airspeed and angle of bank. If, however, the variometer starts to show sink for a fair proportion of the time, the pilot will once more have to alter the position of his circles.

The strongest upcurrents are most often found in the central cores of thermals and so there might appear to be some benefit in keeping in the very middle by making the smallest possible circles. Unfortunately small circles can be achieved only by flying at increased angles of bank; this puts more load on the wing, with the result that the sinking speed is increased. As the rate of climb of the glider is equal to the

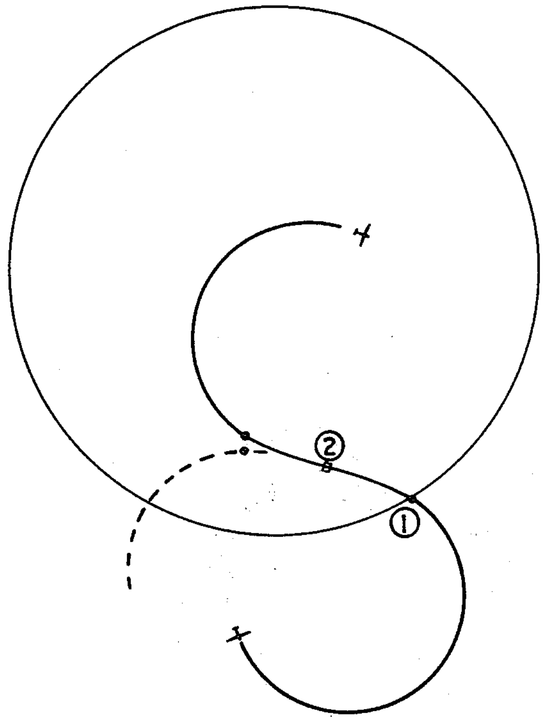

Fig 3.9 Reversing direction of turn. If most of the circle is outside the best lift, the 'surge' method of centring (described in previous figure) will do no good. See dotted line

1 The pilot can shift his path into better lift by straightening up on feeling the surge and then

2 Starting to turn the other way.

This situation can be recognized by the tendency for the bank to increase on entering the thermal and also by the fact that most of the circle has been outside the thermal. The situation should be compared with Fig 3.8 where, if most of the circle is inside the thermal, the effect of the surge will be to reduce the angle of bank

If the reversal of the turn is left until too late, the result may be worse than before. A beginner is not recommended to reverse his direction of turn. He will find it simpler to use the 'Best heading' technique

vertical speed of the thermal less the sinking speed of the glider, it will not pay to reduce the radius of the turn too much, or else the increase in the sinking speed will be greater than the improved strength of the upcurrent at the centre of the thermal. Turns of about 30° are a good compromise to start with, although the skilled pilot may circle at both steeper and flatter angles of bank than this. At 30° of bank a glider flown at 40 knots will take 23 seconds to make a complete 360° turn, the diameter of the circle being 500 ft. Looked at another way, the time taken to fly across the diameter of a circle of this size would be $23/\pi$ seconds–7 seconds. Later on this matter of angles of bank will be dealt with more fully (Chapter 16).

It is important, when circling, that the glider is flown smoothly and accurately. The angle of bank and the airspeed must be kept as steady as possible and there should be no slip or skid. Skill in doing this can only be obtained by practice; accurate turns are most easily made by watching the nose move around the horizon, and not by looking downwards. It is very easy to get into the bad habit of looking at the airspeed indicator every few seconds. This makes flying tiring, and in any case the speed can be kept steadier by reference to the attitude of the glider and the noise it is making.

Variation of Bank due to Location in Thermal. An addition clue for the location of the glider in relation to the core of the thermal is often given by the tendency for the angle of bank to vary. If one wing is in a part of the thermal which is going up more rapidly than the air in which the other wing lies, then the first wing will tend to rise. When circling concentrically to the thermal, the effect of this is negligible since there is only a constant slight moment trying to reduce the angle of bank. However, when circling eccentrically the continual changes may be noticeable. There are two common situations. In the first, where the glider's circle is only slightly eccentric to the thermal, there will be two points where there is no tendency for the angle of bank to be changed and for the remainder of the circle there will be a tendency for the angle of bank to be reduced. The second situation is when the core of the thermal lies completely outside the glider's circle. When the glider is furthest from the core there will be the same tendency for the angle of bank to be reduced, but when it is closest there will be a marked tendency for the angle of bank to be increased. This effect is often noticed when circling in rough air, the sequence as the pilot flies round being: surge up, angle of bank increases, surge down. When this is noticed there is unmistakable evidence that the centre of the thermal lies outside the circle. The solution is to continue round the circle, straighten up when the surge is felt, fly straight for 3–4 seconds, and then circle the same way as before.

SPEED VARIATIONS

If a glider is flown in perfectly calm air and the stick is pulled back, the speed will decrease and the glider go up, or not continue down as rapidly as before. The alterations in height due to quite small alterations in speed are surprising. For example, if the speed is reduced from 45 to 40 knots the glider will be 18 ft higher than it would have been had it continued at 45 knots. This means that if the reduction in speed was spread over 5 seconds a perfect variometer would show an alteration in sink of 2 knots for that period. In practice the variometer has some lag and the alterations in its readings will not be so great, but they are still appreciable. The converse is also true, if the speed is increased the variometer will show a greater rate of descent while the alteration in speed is taking place.

This is a matter of some importance when thermal soaring because if the airspeed is allowed to vary considerably the pilot can easily mistake a 'stick thermal' for the real thing. The best solution is to fit a total energy variometer (Chapter 18), which, in any case, is quite essential for serious soaring. Without it the pilot should try to keep the speed as steady as possible and to ignore minor variations in the variometer readings caused by movements of the elevator control. This 'stick thermal' effect is another reason for the beginner to avoid altering the position of his circles until he has done two complete ones with consistent results, and is quite sure in

which direction he wants to move.

The ability to centre accurately and quickly in thermals is essential to getting the best out of the existing weather and making successful cross-country flights. Every opportunity to practice should be taken while soaring locally, even to the extent of leaving thermals before reaching the top so as to search out and centre in the largest number of thermals possible in a given period of time.

THERMAL STRUCTURE AND FURTHER CIRCLING TECHNIQUE

Although the precise structure of thermals is not fully understood, it is now clear that on many occasions a thermal bubble is in the form of a vortex ring, or doughnut shape, with the air in the bubble circulating as shown in Fig. 3.10, like a smoke-ring. The air in the middle of the ring will move upwards more rapidly than the ring itself, whilst the air in the outer part will descend relative to the bubble, although still ascending relative to the ground.

The circulation within the thermal has two noticeable effects on the circling glider. In the top part of the bubble the glider is in a region where the air is going upwards and outwards; consequently, unless it is centred perfectly, it will tend to be pushed off to one side. Conscious effort will be needed on the part of the pilot to keep centred. On the other hand, a glider in the lower part of the bubble is in a zone where the airflow is upwards and inwards; centring here is almost automatic.

This concept of the vortex ring shape explains many features which have puzzled pilots for a long time. The sudden increase of airspeed often experienced on entering a thermal is easily explained by the outward airflow near the top. It also explains the way in which comparatively small differences in height between gliders can lead to a large difference in the achieved rates of climb. The glider in position 1 of Fig. 3.10 where the rate of rise of the air is equal to the sinking speed of the glider, will just hold its own. But as the thermal bubble rises the glider will gradually lose

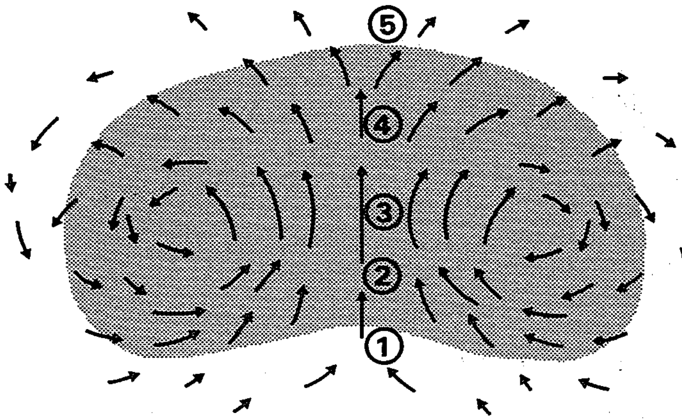

Fig 3.10 Section through vortex ring thermal. As the whole thermal bubble, shown shaded, goes upwards the air contained in it circulates. Notice that the air at the top is flowing upwards and outwards, and at the bottom upwards and inwards

height in the weakly rising wake. A glider slightly higher, in position 2, will climb gently and then, as it rises up into the middle of the ring, more and more rapidly. It will achieve the maximum rate of climb in position 3, and then hold a position which will be constant in relation to the thermal bubble itself (position 4).

A glider first meeting the bubble in position 5 will experience weak lift which will gradually increase and then become steady; the glider will settle close to position 4.

This picture shows the weakness of looking on thermals as being good or bad as a whole. The quality of the thermal, to the pilot, will depend on the part of it that he encountered; striking it lucky just above the bottom he will go romping up, whereas another glider hitting the same thermal at the same time 1000 ft higher may achieve only half the rate of climb.

Normally the larger thermals are found higher up, and this is particularly noticeable in the first few hundred feet above the ground where most of the lift is in small patches. A horizontal cross section through a thermal is usually taken as circular and this is probably not far from the mark, although

with a strong wind the cross section may be oval, with the major axis stretching up and down wind. When two thermal bubbles go up side by side, at low altitude, the lift will be found in two circular areas, but they may gradually join and the area of lift take the form of a figure of eight. Finally when the thermals have merged the cross section will once again be of roughly circular shape.

The edges of the upcurrent may or may not be sharply marked. If a thermal is encountered when it is single, the edge can be felt quite clearly and it will be found that the lift increases progressively towards the centre. At a later stage in development a cross section may consist of a larger area of weak lift, with a smaller region of stronger lift caused by another thermal travelling up in the wake of the first. The outside edge of the wake may be less well defined, but the boundary of the smaller will probably be clearly felt. This situation is often encountered; the pilot on flying into the wake notices the turbulence and weak lift, and on penetrating further feels a real surge as he enters the better lift of the following thermal.

There is no reason why the second bubble should travel up in the centre of the wake, nor why, if the wake is large, two or more bubbles should not go up side by side. In these circumstances the concept of 'centring' in the thermal is apt to be misleading. If a pilot circling in what he imagines to be the centre of the thermal notices that another glider circling nearby is gaining on him, he can decide to shift his circles in that direction. But on doing so he may find that the lift does not improve until he has reached the other glider. What has happened is that both gliders were circling in separate zones which were travelling up in the large wake of an earlier thermal.

Sometimes when thermals are large, and this more often occurs later in the day, the edge of the thermal is ill defined and the entry into the best lift very gradual. Since thermals of this type are found only on occasions when their life is longer than usual their smoothness is presumably due to their having had time to settle down; the core area having become larger and less disturbed.

When the area of lift is large and uniform the pilot can fly around at small angles of bank, exploring quietly for anything better. In order to obtain the maximum rate of climb he will naturally wish to sink down through the air as slowly as possible, and should threfore fly at a speed corresponding to minimum sink.

When the thermal is small, or there is only a small area of good lift inside a large thermal, it will be desirable to make steeper turns. The question of the precise airspeed and angle of bank at which the glider should be flown is complicated as it depends on the characteristics of both the glider and the thermal; it is here that our knowledge of thermal structure is somewhat inadequate. Precise information regarding the size of thermals and the distribution of lift across them would not only enable us to improve circling technique with existing gliders, but would also enable us to design new aircraft better tailored to the air in which they fly.

The strength of a thermal can vary widely. In some parts of the world rates of climb in clear air of well over 10 knots (1000 ft/min) are usual, but in Britain an average rate of climb of more than 4 knots (400 ft/min) is good.

DOWN CURRENTS

In thermal weather, unless the air close to the ground is to become very thin, it is inevitable that air must move in to take the place of that which goes up. This can happen by horizontal movement, such as is manifest in sea breezes, and in the wind which blows in towards the centre of a group of mountains during the day. However, a simple sum will show that if this were the only method a howling gale would occur round the coast every time there was a day with a few thermals. This is not the case, because there are downcurrents to help balance the upcurrents. Apart from large scale subsidence associated with anticyclones, downcurrents take two distinct forms; the gradual downward movements which take place over large areas which are unfavourable for thermals, such as a large lake in the middle of a land mass, and the sink found between individual thermals. Surprisingly enough, downcurrents do not often spread themselves uniformly

over the area which is not occupied by thermals, but tend to be more concentrated. They are often found close to the thermals and also underneath and in decaying clouds. Downcurrents are not usually as strong as the thermals, and therefore they must cover a larger area. As experience is gained the pilot will devote considerable effort to avoid them.

SEARCHING FOR THERMALS

The technique of making use of thermal lift is not particularly difficult, but the problem of finding thermals, and particularly of finding good ones, is a matter in which no one in the world is a complete master.

Thermals themselves are invisible, but there are occasions, unfortunately few, when the effect of them is directly apparent.

Smoke. If a large mass of smoke is seen rising to appreciable heights, more rapidly than seems usual, this indicates a thermal. Large factory chimneys, bonfires, burning stubble, and heath fires often act as pointers in this way.

Dust. Thermals starting from dry, bare ground may carry a quantity of dust with them which can be seen in the same way as smoke. If the thermal is very strong it may start a dust devil.

Birds. A surprisingly large number of birds indulge in thermal soaring. In England kestrels, buzzards, gulls and rooks can be found soaring at any height up to cloud base. All these birds are far better soaring pilots than humans can ever hope to be; not only have they far more experience, but although their sinking speed is not greatly different from that of a glider, their manoeuvrability is so magnificent that they can use small areas of lift useless to us. Birds seldom practise turns for fun, so if a bird is seen circling, it is almost certainly soaring. Some birds soar in thermals when making cross-country flights (e.g., seagulls). Others, whose primary interest is watching the ground for their prey, (e.g., hawks) like to stay over roughly the same area at a constant height, low enough to see small animals. Consequently, once at this height, they may choose to operate in lift which will just maintain them there; this is not likely to be the best thermal.

Various other birds, such as swallows and swifts, are often seen in lift. They are not making use of the thermal itself but merely chasing the insects which have been carried up in it. They are useful as indicators, but unfortunately seldom carry their chase very high.

Other Indications of Thermals. Occasionally various odd things like pieces of paper, plastic bags, and butterflies get carried up in strong thermals. Once they have gone up, these things have to come down again, so unless a mass of them is seen together, they do not necessarily show the presence of a thermal. Gliders near home are to some extent unreliable, as their pilots may only be circling for practice; along competition task routes, however, thermals will be marked by them.

FINDING THERMALS BY LOOKING AT THE GROUND

Thermals tend to form in a roughly cellular pattern with downdraughts between them. If the country is uniform the pattern will exist fairly evenly and this cellular distribution will also occur over broken country when the wind is strong, or the air wildly unstable. However, on the majority of soaring days any pattern will be considerably modified by the type of country below.

In general, surfaces which are dry or dark, and those which heat up quickly, are the most likely thermal sources, although they will be affected by such things as the amount of shelter from the wind, the aspect of the slope in relation to the sun, and their contrast to the surroundings.

To be of any value to a glider pilot, the thermal must be several hundred yards across, and such a thermal can only come from an area even larger than a good-sized field. Normally dry earth fields, corn crops, towns and runway airfields can be regarded as likely sources.

Thermals seldom come off continuously from a particular piece of ground; it is more likely that the air will go up for about 5 minutes, and then there will be nothing for the next 15 minutes or so until the area has been sufficiently rewarmed. The rate of heating will be slow if the surface is in shadow, and for this reason thermals are seldom found over ground which has been in the shade for more than about 10

minutes.

When a thermal rises air has, of course, to flow in to take its place. The wind upwind of the source will increase, downwind it will be less, and on either side blow inwards. Observation of this effect is sometimes useful when trying to catch thermals from wire launches, since by looking at windsocks it may be possible to determine the right moment to be launched. However, when searching for thermals from the air this method cannot often be used owing to the lack of suitable indicators.

If a thermal cannot be discovered by local variations in the wind, and there are no smoke or bird signs, then it is quite impossible to find a definite thermal by looking at the ground. All that can be done is to assess the probability of thermals coming from particular sources. The pilot must study the type of country below him, decide which is the most likely-looking area, bearing in mind the difference in surface, and the cloud shadows, and then try to assess the probable drift of the thermal.

When the thermal rises it will move away downwind, and it is useless looking for lift immediately over a possible source. Since the exact strength of both the upcurrent and the wind are not likely to be known, it follows that neither is the position of the thermal even if the source is obvious. For this reason a pilot stands a much better chance of finding a thermal which he thinks has come off a particular spot if he flies straight up or down wind through the region in which he thinks it is likely to be found. If he flies across wind he may easily miss it.

EFFECT OF CLOUD SHADOWS

If the air is very dry no cumulus will form, but 'dry' thermals may still exist, although invisible in the clear sky. The pilot will have only the variations in surface to help him search, but thermals may be more regularly distributed owing to the absence of cloud shadows. On a day of cumulus cloud the ground and the air covered by shadows will be cooler than the ground and air in the sunlight, and the cooler air will drift downwind with the shadows. It sometimes happens that the cooler air will undercut the warm air and act as the initial boost to the starting of a thermal. It may pay, therefore, to search for lift downwind of a likely looking source which, having been in sunshine for some time, has just become covered by a cloud shadow. It must be remembered that it will take some time for the thermal to come up to the level of the glider. If the glider is at only 1000 ft, the time will be two or more minutes unless the thermal is exceptionally strong.

WIND SHADOW THERMALS

On strong wind days it is often found that the best thermals come off places sheltered from the wind. There seem to be three reasons for this.

1 A wind always produces mixing of the lower layers of the air.
2 If the air is moving it can only be over the thermal source for a short time.
3 The wind, by increasing the evaporation of the surface moisture, will cause a reduction in temperature.

As all these effects are eliminated or reduced over areas sheltered from the wind, it will be better to look for thermals to the lee of large wind breaks, particularly if the area is facing the sun. Downdraughts caused by a slope may, however, prevent the formation of such thermals locally.

FINDING THERMALS BY THE STUDY OF CLOUDS

Broadly speaking, cumulus-type clouds can be divided into simple individual clouds of short duration, and those which once started develop a circulation of their own, drawing in additional air and often growing into large cumulo-nimbus. These may last for several hours.

We will deal first with the small fair weather cumulus. When the top of the thermal reaches condensation level a cloud starts to form, and this cloud goes on growing while the thermal is active, and possibly to some extent afterwards. When the air ceases to rise above condensation level the cloud

will start to decay, and the time taken for decay is roughly the same as that taken for growth. It therefore follows that about half the clouds in the sky are dying and half are developing. Fortunately, clouds look different in their various stages of growth and decay, and while the difference is not very marked, the pilot must learn to distinguish between them if he is ever to be proficient at thermal soaring. The life of a simple cumulus cloud is about 20 minutes or less.

A cumulus starts as a small collection of wisps. After a time these wisps grow in size and amalgamate and the cloud takes definite shape with a flat bottom. The cloud increases in height and size, and the top and edges get firmer in outline and more rounded. As decay starts, the cloud gets less definite in shape and loses its flat bottom. As the process continues, rifts may appear in the body of the cloud, and it breaks up into separate wisps before finally disappearing.

Normally the cloud will start to decay shortly after the bottom of the bubble reaches cloud base. If the glider is appreciably lower there will be little point in heading towards any cloud which has reached its prime, since unless another bubble is travelling up in the same path no lift will be found underneath. The pilot's job is to select clouds in the active stage of growth. He can teach himself this firstly by noting the shape of the active clouds, and secondly by keeping a minute-to-minute watch on particular clouds to see what they do.

This assessment of clouds is a difficult thing to learn, and it needs constant practice to become proficient, but much can be done by watching clouds from the ground and noting their characteristics in differing weather.

From close to, in the air, the problem is much more difficult because the cloud loses so much definition, and it is exceedingly hard to distinguish between the first wisps of a growing cloud and the last fragments of a decaying one. Colour is sometimes a help, as when seen under similar conditions of lighting a growing wisp will appear whiter and brighter than a dying one of the same size. This is not due to the cloud becoming dirtier, but to droplet size; the smallest ones evaporate first.

From near cloud base it is often difficult to judge both the size and quality of other clouds, but much can be learnt by looking at their shadows. Cumulus clouds are seldom very active when large areas of the ground are covered in shadow, so if the pilot sees signs of this ahead of him, it will probably be wise to make a detour to keep over sunlit ground.

If the clouds are bigger it often happens that a large proportion of the cumulus in the sky is active in one part or another. This may be due, especially in light or no wind conditions, to one thermal following up closely behind another from the same source, or a thermal rising into an area already occupied by an existing cloud. Days may even exist when every cloud is active, but they are rare.

The thermal feeding the cloud will slope up towards it and, as mentioned earlier, it is easiest to locate this lift by flying straight up or down wind. The strongest lift is frequently obtained under the darkest, and therefore thickest, part of the cloud, but the position underneath the cloud in which the best lift, or in fact any lift, is to be found is not necessarily either on the upwind side or under the middle. It is modified by any wind shear at or near cloud base. Such shear will bend the thermal as it goes up and the lift may be found towards one or other of the crosswind sides of the cloud, depending on whether the wind veers or backs with height. Once the position is found for a particular cloud, for instance, on the sunny side, this is likely to hold good for other clouds during a considerable period.

If cumulus are growing upward very rapidly and the sky is developing a thundery appearance, lift may be so strong that the pilot finds himself being sucked rapidly into the cloud. The airbrakes should be opened immediately and the glider flown straight and fast away from the lift, or the darkest part of the cloud. On such days the inexperienced soaring pilot should break off circling at least 500 ft below cloud base, or more if the variometer starts to show more than a normal rate of climb.

CLOUD STREET FLYING

If the wind is strong the clouds will often be seen in lines stretching up and down wind, the distance between the clouds

varying from a half to several miles. The clouds are usually separate entities ranged along these lines, but on some occasions may form in continuous streets when it is possible for the glider pilot to maintain or gain height by flying straight along underneath. Usually, however, the good lift is confined to isolated areas underneath some of the clouds, but it is frequently found that there is very little sink when flying between clouds in the same line. On the other hand, very strong sink is often encountered under the blue sky between the lines. On this sort of day the pilot should not attempt to cross from one line to the other unless he is near cloud base, and even then should go square across and not diagonally in his desired direction.

It often happens that a whole line of cloud, having been active for some time, dies. This would appear to be due to the thermal sources of one line becoming covered by the shadows of another line. The pilot must be prepared for this to happen, and if he finds that the lift under his own cloud is dying, and that the clouds both up and down wind look ineffective, he must be prepared to try to go cross wind to another street rather than continue a futile search along his own.

If clouds are visible the fact that the lift is arranged in streets will be shown by the orderly lines of cloud. On cloudless days, or in the late evening, when almost all cloud has faded away, thermals may still lie in rows stretching up and down wind. If this is suspected, the best chance of finding the next thermal will occur if the glider is flown precisely up or down wind, the direction of which should have been determined by observing the way the glider drifts when circling. When trying to stretch a glide, as for example at the end of a distance flight, flying precisely down the line of thermals may make a difference of 15 miles or more, because even if there is no usable lift, there may be streets of weak upcurrents persisting until quite late in the evening. It is best to avoid flying at a gentle angle to the line of the wind, because the glider will have to travel a long way on its diagonal path before it again comes across a street which may contain some lift; if the intended track is diagonal to the wind, then it is better to fly up or down wind using lift, and then across wind more or less at right angles to it towards the next street.

LOCAL SOARING

Before anyone can safely go across country, he must acquire skill in using thermals by putting in some hours of local soaring. Initially, the effort will be just to stay up, but later, as skill is obtained, the emphasis can change to concentrating on finding thermals quickly, making the best use of them and getting orientated in the air.

Initially, the pilot will be briefed to keep within easy reach of the airfield so that should he fail to find lift, or encounter large areas of sink, he will still be able to return to base with sufficient height to make a comfortable landing. If there is no wind, the old empirical rule of 4 miles for every 1000 ft with nothing for the last 1000 is just all right for most club gliders, although it does not leave much in hand for large areas of sink. If there is an appreciable wind the pilot should not let himself go so far downwind of the airfield that he will be unable to get back. This most common mistake on early soaring flights occurs when the pilot drifts in lift away from the airfield, decides that he is getting too far and flies upwind again. He then runs into weak lift, and circles in it without gaining much height; without realizing it, as far as getting back to the airfield is concerned, he is worsening his position. To avoid this, an effort should always be made to keep well on the upwind side of the airfield, and after climbing up, and inevitably drifting downwind, the search for the next thermal should be made more or less upwind.

Once skill in staying up has been acquired, some pilots tend just to drift vaguely around without much effort to improve their technique; the fact that they find they can stay up without much difficulty is sufficiently satisfying. Instead the pilot should try to improve by learning how to climb more quickly. Having reached cloud base, or the top of the lift he should fly off some distance and see how quickly he can find another thermal and climb up again.

During his first few thermal flights the pilot will find that to keep in lift requires a great deal of concentration, but he must remember that he is not alone in the sky. A continuous lookout for other aircraft is essential. If he can work his way upwind of the airfield and find lift there he will find every-

thing much easier. Worries about getting back to the field are eliminated, there is greater freedom of search, and more time to look around.

To begin with, each thermal climb is an event in itself, with its own moments of doubt and exhilaration. But as the pilot gains experience he will see each climb as merely one step in the whole flight, and will find that less concentration is required when going up. Instead of just sitting back and admiring the view, he should teach himself to consider what he is going to do when he reaches the top of his thermal, so that when he does arrive he can fly straight off in the intended direction.

It is impossible to lay down hard and fast rules to be followed when searching for lift. In general the pilot should concentrate on the clouds if he is near cloud base, assessing the shape of individual cumulus and their distribution. If, however, he is low down, the clouds will tell him little except —and this is important — whether the area as a whole is active or not. Unless there is any direct indication of a thermal, all that can be done is to consider the country underneath, and decide which area within easy reach looks the most likely. Bearing in mind the height available for the search, he should then fly over and downwind of this area what he can find.

Roy's Notes:

The "Worst Heading Method" can be simplified to the following Rule:
When the vario is at its lowest point, your inside wing is pointing at where the thermal is. Move the circle toward that area.
Then resume the turn.

The "Best Heading Method" can be simplified to the following Rule:
As the vario needle rises, shallow out the turn and move the circle toward the area that is making it rise. Then resume the turn.